DOES PERSISTENCE IN USING R&D TAX CREDITS HELP TO ACHIEVE PRODUCT INNOVATIONS?

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Abstract

R&D tax incentives are a common policy instrument used in many countries to foster firms' investment in R&D and innovation outcomes. However, evidence on the effectiveness of this instrument is still scarce. In this paper we analyse the effectiveness of persistence in the use of R&D tax credits by firms on the achievement of product innovations. Using a representative sample of Spanish manufacturing firms over the period 2001-2014, we first estimate persistence using a duration model accounting for firm observed and unobserved heterogeneity. Our results are consistent with the existence of negative duration dependence in the use of R&D tax credits by firms, indicating that the probability of ceasing being a recipient firm of tax credits decreases with the passage of time. Second, we estimate a count-data model and find that the number of product innovations introduced by firms depends on R&D tax credit persistence, that is, upon the period of continuous use of R&D tax credits. We also obtain significant differences among large firms and SMEs both in persistence in R&D tax credits and in its impact on product innovations, so that a positive and significant effect of persistence in tax credits on product innovations is found only for SMEs.

Key words: R&D tax credits persistence, discrete time proportional hazard model, count-data model, product innovations.

JEL Classification: O31, C41, H25

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1. Introduction.

During the last decade, the global economic recession has accentuated the need to foster business R&D in many countries. Governments worldwide increasingly rely on both direct support measures and fiscal incentives to promote business R&D. Deductible tax credits for R&D expenditures, usually applied on corporate income tax liability, is one of the main fiscal instruments used to foster business R&D investments (Appelt *et al.*, 2016). By reducing the cost of capital, these tax credits are supposed to stimulate and correct for suboptimal R&D investment by firms.

The recent empirical evidence on the effectiveness of tax credits predominantly documents a positive effect on R&D investments, as reported in Becker (2015) and references therein. However, the literature is scarce in analysing whether there is persistence in the use of R&D tax credits and also on whether the continuous use of tax credits increases the innovative performance of recipient firms. As suggested by David *et al.* (2000), and explained in Czarnitzki *et al.* (2011), tax credits are expected to have a significant effect on R&D investment in the short run, and a small effect in the long run. This time pattern may to be due to the fact that firms are likely to use tax credits to first finance R&D projects with the highest private rate of return, so that tax credit users are more prone to focus on projects with short run prospects. Thus, by inducing spending in those R&D projects with greater expected profitability, tax credits recipients are expected to obtain a higher number of product innovations, as compared to non-recipient firms. However, as firms continue to use R&D tax credits, they are induced to invest increasingly in less profitable projects, with less expected innovation outcomes. Following this line of reasoning, in this paper we test the hypothesis that the effectiveness of this policy instrument in terms of innovation output depends crucially on the continuity of its use, that is, we postulate that persistence in claiming R&D tax credits is positively associated with innovation results, although its impact may be non-linear, that is, it may change as persistence increases.

The aim of this paper is to investigate the effectiveness of the persistence in the use of R&D tax credits on the innovative performance of recipient firms. In particular, we address two empirical research questions. The first research question aims at analysing the pattern of persistence of firms as recipients of tax credits. Claiming R&D tax credits involves not only administrative costs, but also handling additional accounting records and dealing with tax authorities, what may imply a higher risk of tax inspection. That is, the procedure to claim R&D tax credits is costly, and some of these costs may be irrecoverable (sunk), inducing firms to continue claiming them once they have started, and thereby leading to persistence in the use of R&D tax credits. Our hypothesis here is that firms that start participating in tax incentives programs (that is, that start claiming tax credits) will tend to continue participating given the sunk costs associated with administrative costs and acquisition of knowledge and experience involved in the process. As firms benefit from tax credits in a continuous way, they may improve the way they organise and manage their R&D spending and tax claiming, which will allow them to continue benefiting from tax credits.

In addition, we also investigate which firm and market characteristics reinforce persistence of R&D tax credit utilization by firms, i.e., which firm and market features affect firms' propensity to claim tax credits in a continuous way. To be able to benefit from tax credit incentives a first condition is that the firm invests in an R&D projects that comply with the legal definition of R&D according to the tax authority. When tax incentives are designed as deductions from the firms' corporate tax liability, only firms with enough (internal or external) funds to finance R&D investments and with positive taxable income will be able to claim them. Thus, conditional on investing in R&D, those factors contributing to generate positive taxable income regularly may lead to persistence in the usage of tax credits. In particular, we may expect that being a large firm, internationally marked oriented, with a high market share and with a reduced number of competitors, are features that we may consider as making the firm more prone to repeatedly benefit from tax credits. By contrast, being a young, small firm, facing many competitors in the market and having a low market share are characteristics that may decrease the chances to generate positive tax incomes in a continuous way, and thus to benefit from tax credits on a regular basis.

The second research question is whether persistence in using R&D tax credits increases the innovative performance of recipient firms. In particular, we investigate whether continuity in the use of R&D tax credits, controlling for the amount of R&D investment, affects the achievement of product innovations by firms. By inducing firms to invest in the most profitable R&D projects first, tax credits are expected to improve the innovative performance of firms that claim them. However, the impact of tax credits on firms' innovation returns is likely to be non-linear, given that as firms continue to use

R&D tax credits, they will be induced to invest increasingly in less profitable projects, with less expected innovation outcomes (David *et al*., 2000; Czarnitzki *et al.*, 2011). Since persistence in using R&D tax incentives is conditional on R&D spending, our purpose then is to investigate whether persistence in benefiting from R&D tax credits, controlling for R&D investments and R&D experience, and other firm and market characteristics, is positively and non-linearly associated with the achievement of product innovation.

The research questions raised above are relevant from a policy point of view: if persistence in the use of R&D tax credits is desirable because it leads to higher innovation results, it is important to know what factors induce firms claiming R&D tax credits on a regular basis. In addition, it would suggest that fiscal policies should aim at providing a streamlined, predictable and stable over time tax scheme in order to facilitate firms continuous use of tax credits. Finally, to take advantage of tax incentives, firms may simply reclassify unrelated operating expenditures as R&D investments (Hall and Van Reenen, 2000. Thus, if the final goal of this policy instrument is to increase firms' innovation outcomes, it is important from a policy point of view to evaluate the impact of R&D tax credits on innovation results, beyond its impact on R&D investments.

To investigate these issues, we use firm-level panel data drawn from the Spanish Survey of Business Strategies (*Encuesta sobre Estrategias Empresariales*, ESEE henceforth), a representative sample of Spanish manufacturing firms, for the period 2001-2014. This is a comprehensive survey that includes information at the firm level on a number of issues, including R&D expenditures and innovation activities, and also the use of R&D tax credits. First, we focus on those firms performing R&D and claiming R&D tax credits, and use duration model techniques to investigate whether there is duration dependence in the use of tax credits. We distinguish between large firms and SMEs and investigate whether persistence (the length of the period of continuous use of R&D tax credits) and its drivers differ among them. Secondly, we investigate whether R&D tax credit persistence is positively associated with a higher number of product innovations, also distinguishing between large firms and SMEs.

The contribution of this paper to the existing literature is manifold. First, a number of studies have analysed firms' persistence in R&D, both at the input and at the output level,[1] and although persistence in the use of R&D tax incentives might be closely related to persistence in R&D engagement, there is a lack of empirical studies explicitly analysing firms' persistence in using R&D tax credits. The exception to this, to the best of our knowledge, is the work by Busom *et al.* (2017) who analyse persistence in firms' participation in both R&D tax incentive and subsidy programs. They investigate whether participation in one of these programs predicts future participation in the same program, that is, the extent of inertia or state dependence, and also whether there is cross-persistence between the two programs. Our paper differs from them in that we analyse persistence using duration models, which allows us to investigate the patterns of continuity in using R&D tax credits, and in that we also analyse the impact of persistence in using tax credits on the achievement of innovation results.

Secondly, most of the literature has focused on the effect of tax incentives on R&D investments, or input additionality. By investigating whether persistence in R&D tax credit participation is positively associated with the achievement of greater innovation results, our paper contributes to the literature on output additionality of tax credits (see, e.g., Czarnitzki *et al*., 2011, Cappelen *et al.,* 2012, Castelacci and Lie, 2015, Bodas Freitas *et al*., 2017, Bösenberg and Egger, 2017, Sterlacchini and Venturini, 2019). Our novelty here is that we analyse the impact of persistence in claiming tax credits on the achievement of product innovation, and explore the possibility that this impact may be non-linear, and to the best of our knowledge, this is the first study to address output additionality of R&D tax credits from this point of view.

Thirdly, by distinguishing between large firms and SMEs, we also contribute to the literature of the different nature of innovation strategy by firms' size and the importance of considering this source of firm heterogeneity when analysing persistence in using R&D tax credits. Finally, this paper also relates to the literature on the factors

[1] Persistence in the achievement of innovation results, such as patents or product innovations has been analyzed, among others, by Geroski *et al.* (1997), Crepon and Duguet (1997), Malerba and Orsenigo (1999), Cefis and Orsenigo (2001), Cabagnols (2006), Roper and Hewitt-Dundas (2008), Martínez-Ros and Labeaga (2009), Raymond *et al.* (2010), Triguero and Corcoles (2013), Ganter and Hecker (2013) and Antonioli and Montresor (2019). Persistence in R&D engagement has been documented by Mañez *et al.* (2009, 2015), Artés (2009), Arqué-Castells (2013), Triguero and Corcoles (2013), Beneito *et al*. (2014, 2015), and García-Quevedo *et al.* (2014) for Spanish manufacturing, Peters (2009) for German firms, and Piva and Vivarelli (2007, 2009) for Italian firms, among others.

influencing the achievement of output innovation by firms, and the differential impact of these factors according to the size of firms.

To anticipate our results, we find empirical support for the existence of persistence in the use of R&D tax credit by firms. Using duration models, we obtain evidence of "negative duration dependence", which means that the probability of ceasing in the use of R&D tax credits decreases with the passage of time, suggesting that claiming R&D tax credits is partially a self-sustained process. Second, we find significant differences in the drivers of persistence of large and small firms, which are consistent with their differences in terms of firm and market characteristics. Third, we obtain that persistence in the use of R&D tax credit has a significant and positive impact on the achievement of product innovations, in particular in the case of small firms. In addition, our results suggest that this impact is non-linear, so that persistence in R&D tax credits exert a positive but decreasing effect on the expected number of product innovations. This finding is consistent with the idea of David *et al* (2000) and Czarnitzki *et al*. (2011), among others, that as firms continue to use R&D tax credits, they may be induced to invest increasingly in less profitable projects, with less expected product innovation.

The rest of the paper is organised as follows. Section 2 reviews related literature. Section 3 describes briefly the main features of the Spanish R&D tax credit system. Section 4 presents the data and some descriptive statistics. Section 5 contains the empirical model and econometric procedure. Section 6 discusses the main results and Section 7 concludes.

2. Literature review on R&D tax credits.

There is a body of research that has mainly focused on testing whether public support to R&D programs induce what is known in the literature as input additionality, that is, substitution of private by public funding, or, on the contrary, they contribute to increase private R&D investments.[2] Most of the studies on input additionality of R&D tax credits

[2] For a review and critical discussion of the R&D literature on the effectiveness of major public R&D policies in increasing private R&D investments, see Becker (2015).

use a microeconomic perspective and have been undertaken at the firm level.[3] The results of these studies are mixed, depending upon the sample of firms and the period analysed, and also on the methodology used. For instance, Lokshin and Mohnen (2012) found partial crowding-out effect of tax credits in the case of Dutch large firms, whereas Baghana and Mohnen (2009) found a similar result for large Canadian firms. Dechezlepetre *et al.* (2016) found strong positive effects of R&D tax credits on firms R&D spending and patenting in UK firms. The works by Yang *et al.* (2012) and Chen and Gupta (2017) provide evidence of a positive impact of R&D tax credits on R&D investments for high-tech Taiwanese firms. Crespi *et al*. (2016) document the heterogeneous effect of tax credits in promoting innovation investments of Argentinian firms. More recently, Sterlacchini and Verturini (2019) analyse the impact of R&D tax incentives on R&D expenditures over sales for manufacturing firms in France, Italy, Spain and the UK. Using a matching procedure, they find evidence of input additionality effects for the examined countries, except for Spain. They also document that the effects of R&D tax incentives differ between SMEs and large firms, so that a positive and significant impact is obtained only for SMEs.

Regarding the analysis of the "output additionality" of R&D tax incentives, that is, the impact of tax incentives on the achievement of innovation results, such as patents and product innovations, the literature is scarcer. Czarnitzki *et al.* (2011) found evidence of a positive effect of R&D tax incentives on innovation output for a sample of Canadian manufacturing firms and Cappelen *et al.* (2012) find a positive association between the Norwegian tax credit system and the introduction of product innovations. Castelacci and Lie (2015), Bodas Freitas *et al.* (2017), Bösenberg and Egger (2017) are also recent studies dealing with output additionality of R&D tax credits and the results they obtain are mixed.

Apart from input and output additionality of tax incentives, a small number of papers have analysed the factors inducing firms to participate in R&D tax credit. Busom *et al.* (2014, 2017) have analysed the determinants of firms' participation in both R&D subsidies and R&D tax credit programs using a sample of Spanish firms, focusing on the

[3] At the cross-country level, a number of studies have also analyzed the impact of R&D tax incentives on private R&D spending, with mixed results (see, e.g. Bloom *et al*., 2002, Guellec and Pottelsbergue, 2003, Thomson, 2017, and Brown *et al*., 2017, among others).

role of innovation-specific financial constraints and the extend of appropriability of returns. They found significant differences between the use of these two instruments across firms' size, lending support to the idea that these two policies are neither equivalent nor substitutes.

However, in spite of this extensive literature, there is a lack of empirical evidence focusing on the analysis of firm persistence in the use of R&D support programs in general, and in the use of R&D tax credits in particular. Aschhoff (2010) found true state dependence in subsidy program participation in Germany. Busom *et al.* (2017) analyse firm's participation persistence both in R&D subsidy and tax incentive programs using a panel of Spanish manufacturing firms for the period 2001-2008, estimating dynamic models of program participation. They found significant true state dependence of participation in each program, in particular regarding stable R&D performers, and also identified significant differences across programs, suggesting that they are not substitutes. In addition, they do not find evidence of cross-program interactions, that is, of cross-persistence in firms' participation in the two R&D support programs. However, none of these studies have analysed persistence in claiming R&D tax credits and the output additionality effect of this persistence on firms' innovation output, and in this paper, we attempt to fill this gap.

3. Main features of the R&D tax credits system in Spain.

The current R&D tax incentive scheme in Spain was established in 1995, when a new law on corporate taxation was introduced. The scheme, exclusively offered by the central government, allows firms to deduct a given percentage of their R&D expenditures from their corporate tax liability. The R&D expenditures eligible for tax credits are those that accomplish with the definition of the OECD's Frascati Manual. The main characteristics of the current Spanish tax scheme are explained as follows (Labeaga *et al.,* 2014). The design of the scheme is a hybrid system that combines volume with incremental based deductions, so that firms may deduct 25% of their qualifying R&D expenditures and an additional 42% of their incremental R&D expenditures. The maximum amount of credits that may be deducted corresponds to the 35% of the tax liability, and the firm may carry forward the tax credits when these exceed the legal threshold percentage of their tax liability for a given year to the following 15 (or 18) tax periods.[4]

Table 1 reports the evolution of the R&D tax credit system in Spain for the period corresponding to the dataset we analyse in this paper. This scheme is one of the most generous tax deduction schemes among major developed countries regarding R&D expenditures (Appelt *et al.,* 2016). It is important to note that during this period, there has not been any noticeable change in the tax system that could interfere with our analysis of persistence in the use of tax credits by firms and its impact on innovation results.

[Insert Table 1 around here]

In order to benefit from R&D tax credits, a firm must first undertake R&D expenditures that qualify as R&D expenses according to the tax code definition of R&D. Tax credits apply to corporate tax liability and therefore, only firms with positive taxable income will be able to claim R&D tax credits.[5] Thus, all those factors that favour the continuous generation of positive taxable income may be expected to be positively associated with tax credit participation persistence. In general, since engaging in R&D investment is a condition to benefit from tax credits, we may also expect that all those factors behind R&D persistence will also help to explain persistence in R&D tax credit usage. Thus, in our empirical approach we will need to control for the R&D investments and R&D experience accumulated by firms.

4. Data and descriptive analysis.

We use data drawn from the ESEE for the period 2001-2014. This is an annual survey conducted by the *Fundación SEPI* (a Spanish public institution) that is representative of Spanish manufacturing firms. The ESEE provides information at the firm level on an extensive number of issues, including R&D investments and the number of product innovations. Regarding R&D tax credits, firms in the ESEE are asked to answer the

[4] Unfortunately, the ESEE survey does not provide information on the firms' use of carry-forward provisions when claiming tax credits, so that persistence could be also due to ongoing projects rather than repeated participation. We provide a robustness test on this issue in Section 6.3.

[5] Law 27/2014 (https://www.boe.es/buscar/act.php?id=BOE-A-2014-12328) contemplates some exceptions where there is no need to have positive taxable income to claim R&D tax credits.

following question: "Indicate the total value of deductions you have applied in the corporate tax in year *t*. Specify those referred to R&D and technological innovation". From this information, we construct a binary variable taking the value of one if the firms declare that it has claimed R&D tax credits in year *t*. Although the survey is carried out since 1990, information on R&D tax credits is only available since 2001.

Figure 1 provides preliminary evidence on the different patterns in the R&D effort of claimants and non-claimants of R&D tax credits. This figure represents the evolution of the R&D effort of the firms in our sample, measured as the percentage of R&D expenditures over sales, and distinguishing between large firms and SMEs, [6] and between firms that claim R&D tax credits on a regular basis ("Always and entrants tax credits")[7], and firms that never participate in the R&D tax program ("No tax credit"). For the sake of comparison, Figure 1 does not include firms than use tax credits only occasionally. By visual inspection, we first observe that the R&D effort of those firms that claim tax credits on a regular basis is in general larger than the rest. Second, we also observe that many firms do invest in R&D but do not claim R&D tax credits, even though their effort in some periods is similar to that of persistent claimants. Finally, we also observe different patterns in the use of tax credits between small and large firms. We consider that, conditional on identifying the characteristics of the firms under the two categories, the lack of information on tax credits, administrative costs, and the risk of an inspection by tax authorities could explain this behaviour of Spanish firms.

[Insert Figure 1 around here]

Table 2 provides information on the transition probabilities of R&D tax credit status for the sample of firms with positive spending in R&D. A preliminary look at the data shows persistence both in claiming and non-claiming R&D tax credits, being larger for large firms, while transitions between statuses are scarce. More than 86% of non-claimants in one period remain in this status during the following year, while more than 79% of firms claiming R&D tax credits continued claiming them the following year.

[6] In this paper we consider large firms those with more than 200 employees, and SMEs those with a number of employees between 10 and 200. This criterion is different from standard, but it is due to the different sampling procedure of these two groups of firms in the ESEE.

[7] We consider as "Always tax credits" those firms that claim R&D tax credits over the whole period and "Entrants" those that start claiming tax credits and continue to claim them during the observation period.

Moreover, both large firms and small firms are more persistent in non-claiming tax credits (84% and 87%, respectively) than in claiming them (81% and 76%, respectively).

[Insert Table 2 around here]

In Table 3 we present descriptive statistics on the relationship between persistence in claiming R&D tax credits and the achievement of product innovations, that is, the average number of product innovations that firms obtain as they accumulate years of experience in claiming R&D tax credits. The first column indicates, by intervals, the number of consecutive years firms have been claiming R&D tax credits, i.e. whether they are in their first two years of using the program, in their third and fourth year, and so on. We observe that, in general, the average number of product innovations per firm increases as firms accumulate experience in claiming R&D tax credits. Regarding large firms, the average number of product innovations per firm rises from 2.7 during their first 1-2 years of claiming R&D tax credits up to more than 5 when firms accumulate 5-6 years of R&D tax credits experience, and then for the longer intervals beyond 7-8 this average number decreases. In the case of SMEs, the average number of product innovations per firm rises from around 4 during the interval 1-2 to more than 9 during the interval corresponding to 7-8 years of R&D tax credits experience and decreases thereafter. These data suggest a non-linear relationship between the accumulation of experience in claiming R&D tax credits and the average number of product innovations per firm. We will investigate this issue in the econometric section below.

Finally, Table 3 also reports the annual average of firms' R&D expenditures (in real terms and in logs), for both large and SMEs. We observe in both cases a mild increase in firms' R&D expenditures over the years, what could suggest that the factor explaining the higher number of innovations, could be a higher expenditure in R&D. Thus, in order to derive conclusive results on the relationship between persistence in claiming R&D tax credits and the achievement of product innovations we need to turn to the econometric results in section 5, where we will be considering firms' R&D expenditures when estimating an innovation production function. All in all, we may observe that experience in claiming tax credits is important both for innovation inputs (R&D expenditures) and outputs (number or product innovations). However, we also observe that the effect of this experience is non-linear and there might be a threshold for large firms. This evidence is, of course, conditional on other factors and we should control for them in our econometric analysis.

[Insert Table 3 around here]

5. Empirical model and econometric procedure.

In our empirical approach we proceed in two steps. We first investigate the drivers of firms' persistence (duration dependence) in claiming R&D tax credits using duration model techniques. Second, we analyse the effect of this persistence on the achievement of product innovations using count models. In what follows we describe these two steps.

5.1. Persistence in claiming R&D tax credits.

We study persistence in firms' decisions to claim R&D tax credits using duration models. The unit of observation is the firm R&D tax credit spell, defined as a period of uninterrupted use of R&D tax credits by the firm, that is, the number of consecutive years the firm benefits from them. We consider that the spell starts in year j if the firm did not claim R&D tax credits in year j-1 but it benefits from them in year j. Similarly, a spell is computed to end in year T when this is the first year in which the firm does not benefit from R&D tax credits, after several consecutive years of using them. Therefore, we measure persistence in R&D tax credit participation by the extent of continuous use of R&D tax credits by firms, that is, by the length of an R&D tax credit spell.

To analyse the drivers of the duration of R&D tax credit spells (spell survival), we carry out a multivariate analysis to evaluate the effect of each explanatory variable on the risk (i.e., the hazard) that a spell ends, conditioning on all other covariates. We implement discrete time proportional hazard models in which the duration of an R&D tax credit spell is treated as a discrete variable (interval-censored data on a yearly basis) since claiming R&D tax credit is usually made by the firm once a year (at the same time that the firm fills out the form for its annual corporate taxes). The estimation method we use allows for a flexible specification of the baseline hazard, and to control non-parametrically for firms' R&D tax credit spells unobserved heterogeneity, facilitating the identification of the effects of survival time on spell duration (the so-called duration dependence). In particular, we use the following discrete time proportional hazard function:

$$h\left(t, x_{it}\right) = h_0(t)\exp\left(\beta_0 + x_{it}\beta\right)\cdot v_i \tag{1}$$

where $h(t, x_{it})$ is the hazard function, $h_0(t)$ is the baseline hazard function, and x_{it} is a vector of firm and market characteristics. Unobserved heterogeneity is incorporated multiplicatively since in this way it measures a proportional increase or decrease in the hazard rate of a given firm, relative to an average firm. In estimation, unobserved heterogeneity is treated non-parametrically by assuming that there are several different types of firms (or "mass-points" in the distribution of individual heterogeneity) so that each firm has probabilities associated with the different "mass-points" (Heckman and Singer, 1984).[8]

Taking logs in (1) we obtain the following expression, which is our first estimating equation:

$$\log h\left(t, x_{it}\right) = \log h_0(t) + \beta_0 + x_{it}\beta + \log v_i \tag{2}$$

We estimate (2), that is, firms' persistence in benefiting from R&D tax credits, using survival methods. This implies that our dependent variable is binary, taking value one the year in which the R&D tax credit spell ends, and zero otherwise. To analyse the duration of R&D tax spells, we first consider the baseline hazard of our survival model, log $h_0(t)$, which accounts for the risk of spell ending exclusively due to the passage of time, and that is common to all the spells in the sample, after controlling for both covariates and unobserved heterogeneity. Thus, the baseline hazard, which we denote *log (survival time)*, captures the pattern of duration dependence.

5.2. Specification of the hazard function.

We discuss in this subsection the covariates affecting the hazard of R&D tax credit spell ending, i.e., the probability of ceasing in claiming R&D tax credits (or persistence). Since

[8] However, as we get that mass-points are not statistically significant, we will estimate our model using instead a random-effects discrete time proportional hazard model.

there is no integrated framework to analyse R&D persistence, in what follows we introduce the different factors that may lead to R&D tax credit participation persistence, which we classify into three groups. First, as benefiting from R&D tax credit is linked to the innovative orientation of the firm, we consider those factors determining the innovation strategy of the firm. Second, we consider a number of other firm and market characteristics that may induce firms to benefit repeatedly from R&D tax incentives. Finally, we also consider several controls that may influence firms' decision to use R&D tax credits on a regular basis.[9]

First, regarding the innovation strategy of the firm, we include a number of covariates capturing the extent of engagement in innovation activities. We consider that the more innovative oriented the firm is, the more likely is that it will claim R&D tax credits on a continuous basis. In particular, we consider that the accumulation of R&D experience is likely to be positively associated with the probability to engage in R&D in a continuous way and thus, with the probability to claim R&D tax credits on a regular basis. To capture the R&D experience accumulated through past R&D investments we use a measure of the R&D capital stock, as it is standard in the literature (Griliches, 1979). We also include a measure of the degree of innovation success. According to Nelson and Winter (1982), innovative success generates profits that may be reinvested in R&D, thereby increasing the probability to innovate again. Under this approach, we may expect innovative results to be positively associated with the use of R&D tax credits. We include as indicators of innovative success whether the firm has introduced any product or process innovation in the previous period.

In addition, we include an indicator on whether the firm undertakes complementary innovation activities, such as technical and scientific information services, quality controls and/or market and marketing studies for the commercialization of new products. As a measure of the importance of firms' R&D human capital, we include the percentage of R&D employees over the total number of employees, and an indicator on whether the firm has hired R&D employees. Further, we also consider that firms will be more prone to keep investing in R&D, and so to use tax credits regularly, when they can easily appropriate the returns of their investments. As an indicator of the use of legal protection methods and, to capture the degree of appropriability of the

[9] See Table A1 in Appendix 1 for a definition of all the variables used in our analysis.

innovation output, we follow Beneito (2002) and Máñez *et al.* (2015), among others, and include the ratio of the industry-year number of patents and utility models over the total number of firms that have introduced product and/or process innovations. Also, as part of the innovation strategy of the firm, we consider whether the firm engages in internal R&D activities (as opposed to external or contracted R&D activities), and whether the firm reports technological collaboration with other firms or institutions.

A second group of factors that may induce firms to claim tax credits is related to firm and market characteristics. In general, conditional on investing in R&D, those factors contributing to generate positive taxable income (profits) on a regular basis may lead to persistence in the use of tax credits. Therefore, we may expect that being a large firm, with a significant market share, internationally marked oriented, with a reduced number of competitors, are features that we may consider as making the firm more likely to repeatedly claim tax credits. By contrast, being a young, small firm, facing many competitors in the market are characteristics that may decrease the chances to generate positive taxable incomes in a continuous way, and thus to impede benefiting from tax credits on a regular basis.

Following the above discussion, we include the following firm and market factors. The first two characteristics we consider are firms' size, measured as the log of the number of employees, and age. Claiming and obtaining R&D tax credits entails costs since it usually involves keeping additional records and it may imply a higher risk of tax inspection. Large firms with large R&D budgets are more likely to be aware of and apply for R&D tax credits. As compared to smaller firms, large firms are more likely to have better accountant procedures and face lower administrative burden associated with claiming tax credits, since these costs are spread over a large volume of R&D expenditures. In addition to size and age, we include a variable trying to capture the financial capabilities of the firm. In particular, we include the ratio of the firm own funds to short-run debt. This variable may be considered as indicating the firm' availability of internal funds to finance R&D expenditures, and thus to claim R&D tax credits.

Market demand conditions are also likely to affect persistence in R&D activities and therefore in the use of R&D tax credits. When market conditions are positive and firms face expansive markets, it is more likely that a firm will keep in investing in R&D and also in using R&D tax credits, causing persistence. To capture market conditions, we include a variable indicating that the firm declares to be facing a recessive market. We also include an indicator of whether the firm reports to hold a significant market share, together with three indicators of the number of competitors the firm faces in its main market (see Table A.1 for details). We also consider whether the firm operates in a medium or high technological industry, and the percentage of firm' exports over total sales, as a measure of internationalization of the firm.

Finally, as controls we also consider a number of factors that may influence firms' continuous use of R&D tax credits. First, we include an indicator on whether the firm has received public funding related to R&D. Second, we include a measure of market spillover arising from the use of R&D tax credits by other firms in the same market. We consider that a firm may be more likely to claim R&D tax credits in those sectors (or markets) where other firms -their peers- have been claiming tax credits (this could be considered as a sectoral knowledge spillover). When the R&D tax support system is complex (in terms of support schemes and in terms of eligibility), firms may resort to imitate the behaviour of those firms that have adopted the R&D tax credit support earlier. Thus, we expect the propensity of a firm to claim R&D tax credits to be positively associated with the proportion of firms claiming them within the same market -in the previous period-. In order to identify this sectoral or market spillover, we take industry (at 2-digit NACE level) and geographical location (Spanish Autonomous Communities) as the determinants of a firm's market.

A preliminary look at the data to observe duration in claiming R&D tax credits is provided in Figure 2, representing the non-parametric Kaplan-Meier estimates of the survival function of firms. The estimate of the survival function for SMEs is always below that of large firms, indicating that SMEs' R&D tax credits spells are shorter than those of their larger counterparts. Whereas the mean (median) duration of the R&D tax credit spell is 5.7 (5) years for large firms, for small firms is 3.7 (3) years.

[Insert Figure 2 around here]

Finally, regarding the number of R&D tax credit spells, in our sample we have a total number of 2,688 spells. Out of these, we have discarded 248 spells corresponding to firms with three or more spells, since we consider that these firms display a pattern of disproportionate discontinuity in the use of tax credits within the period analysed. Thus, our working sample includes 2,440 spells corresponding to 1,474 firms with one spell (60.4%) and 483 firms with two spells (39.6%).

5.3. The effect of persistence in R&D tax credits on product innovations.

Our next step is to evaluate the effect of persistence in claiming R&D tax credits on firm's innovation output. In doing so, although we do consider R&D expenditures, we pass over the link between using R&D tax credits and R&D spending, mainly for two reasons. First, the relationship between using R&D tax credits and increased R&D expenditures is hard to measure. Secondly, an increase in R&D expenditures as a result of using R&D tax credits may simply reflect a re-labelling of ordinary operating costs or higher wages for R&D employees, without actually implying higher R&D spending (Hall and Van Reenen, 2000). Thus, identifying a positive impact of persistence in the use of R&D tax credits on innovation results is important since it would imply that there has been a true increase in R&D investments beyond reclassifying effects.

We propose to estimate an innovation production function in which R&D tax credit persistence is considered to be an additional input of the firm' innovation process. We measure innovation output as the number of product innovations, that is, our dependent variable is the count of product innovations for firm *i* during time period *t*.

It is standard in the literature to assume that the Poisson distribution is a reasonable description for this type of (count) data. However, one restrictive assumption of the Poisson model is the equality of mean and variance. If this assumption does not hold, and the data exhibits *under* or *over dispersion*, although the estimated parameters may still be consistent, their standard errors will typically be over or under-estimated, leading to spuriously low or high levels of significance. The Negative Binomial model (NB) arises as a natural extension of the Poisson model that allows for *over dispersion*, which is the usual fact in the data. Therefore, the NB model nests the Poisson model, and it is possible to test one specification against the other. The most straightforward approach to adjust a count data model with non-negative counts is an exponential specification as:

$$y_{it} = \exp\left(\gamma \log \hat{h} + \beta' x_{it} + u_{it}\right) \tag{3}$$

where y_{it} is the number of product innovations of firm i in year t, $\log \hat{h}$ is the estimation of the firm survival in using R&D tax credit obtained at the first step, x_{it} are inputs affecting the production of innovations and controls, and $\exp(u_{it})$ follows a gamma distribution.

Taking logs in the above expression, we obtain our second estimation equation, given by:

$$\log(y_{it}) = \gamma \log \hat{h} + \beta' x_{it} + u_{it} \tag{4}$$

As inputs affecting the achievement of product innovations, we include the following variables. First, we use a measure of the R&D capital stock, as it is standard in the literature. This variable captures the experience and the effort in R&D investment that the firms has accumulated across the years, that may be positively correlated with the achievement of innovations. We also include a dummy variable indicating that the firm received public financial support for its R&D investments. Both the measure of R&D capital stock and the indicator on receiving public subsidies may be considered as inputs into the innovation production function and therefore we include them with one lag. We also include a binary variable indicating that the firm is performing internal R&D activities, as opposed to external R&D, and a binary variable that indicates that the firm undertakes complementary innovation-related activities, which may also affect positively to the achievement of innovation outcomes. These complementary R&D activities (collected in the ESEE on a four-year basis) include services of scientific and technical information, works oriented to normalization and quality control, efforts to assimilate imported technologies, marketing studies, design, and other activities. We also include a dummy variable indicating that the firm undertakes technological collaboration with other firms and institutions, and to capture the firm's human R&D capital, we also include the number of R&D employees.

Regarding other controls, we include several variables capturing the foreign and domestic market conditions. We first include a measure of the export intensity of the firm. Firms that participate in international markets are more likely to introduce product innovations as a way to keep their market competitiveness. In addition, we include several indicators regarding the number of competitors in its main market, whether the firm faces a recessive market, and whether the firms enjoys a significant market share. Finally, we also include industry dummies (we group firms in 20 industrial sectors of the NACE-93 classification, as collected in Table A.1), and time dummies.

6. Estimation results.

In this section we report and discuss the results we obtain for our two empirical questions. First, we investigate persistence in firms' decisions to claim R&D tax credits using duration models. The unit of observation is the firm R&D tax credit spell**,** defined as the number of consecutive years the firm benefits from R&D tax credits. Therefore, we measure persistence by the extent of continuous R&D tax credits claiming by firms, i.e., by the length of an R&D tax credit spell. Second, we analyse if persistence in claiming R&D tax credit (estimated in the first stage) stimulates the achievement of innovation results, in terms of the number of product innovations.

6.1. Basic results for the duration of R&D tax credits spells.

Table 4 shows the estimation results of a complementary log-log model for panel data.[10] The dependent variable is the hazard rate of R&D tax credit spell ending. Thus, a negative coefficient estimate for a regressor will be indicating a reduction in the probability of ceasing in using R&D tax credits, and so an increase in the duration of the spell (or spell persistence). To properly measure the factors inducing continuity in the use of R&D tax credits, that is, the drivers of persistence -the duration of the spells-, we select only those firms that invest in R&D and claim R&D tax credits in a continuous way.[11] Column (1) reports the results for all firms in this sample. Further, we also estimate this specification

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[10] We have estimated the hazard function (2) using Jenkins's *hshaz* program that treats unobserved individual heterogeneity non-parametrically (this procedure provides a test for unobserved heterogeneity). However, since the results indicate that unobserved heterogeneity (mass-points) are not statistically significant, we estimate a panel data complementary loglog model with random individual unobserved heterogeneity.

[11] In particular, we include those firms that claim R&D tax credits over the whole period and also those firms that start claiming tax credits and continue to claim them during the observation period.

distinguishing between large firms and SMEs using two size group dummies (for large firms and SMEs, respectively). In this second estimation we allow the estimated coefficients of all explanatory variables to vary depending on the firm being a large firm (more than 200 employees) or a SME (columns 2 and 3, respectively).

[Insert Table 4 around here]

Focusing on column (1) of Table 4, we obtain a negative and significant effect for the variable *log (survival time)*, what provides evidence of negative duration dependence: the probability of spell ending decreases with the passage of time, implying that as time goes by firms experience a longer duration into using R&D tax credits, and/or a lower probability of ceasing in using R&D tax credits. This result is consistent with other studies that have found inertia in fiscal participation programs (Busom *et al.,* 2017).[12] In addition, among the factors capturing the innovation orientation of the firm, we find that the variable indicating that the firm undertakes complementary innovation activities has a negative and significant effect on the probability of spell ending. The rest of innovation-orientation variables do not significantly affect the spell duration. However, this result is not surprising if we consider that we have restricted the sample to firms that regularly invest in R&D, so that they are all innovation-oriented firms. Regarding firms and market characteristics, we obtain that young firms experience shorter spell duration, whereas firms with internal financial resources, firms operating in a med or high-tech industry and export oriented have a longer expected spell duration. These results are also in line with the existing literature on barriers to innovate that provide evidence that young firms, those firms with financial constraints and firm in low-tech industries are less likely to invest in R&D and so less likely to claim R&D tax credit on a regular basis (see, among others, Hall and Lerner, 2010, Czarnitzki and Hottenrott, 2011, García-Quevedo *et al*., 2014).

As regards to other controls, we obtain that both our measure of R&D tax credit spillover, corresponding to the average number of firms within the same market using

[12] Busom *et al.* (2017), using Spanish firm data, estimated a dynamic bivariate probit for firm's participation in R&D subsidy and tax incentive programs and found evidence of inertia or state dependence in the participation in these programs. Nonetheless, they did not find evidence of cross-program interactions, that is, temporal inertia between obtaining subsidies and claiming tax credits.

R&D tax credits, and the indicator of receiving public subsidies increase the spell duration. Our results on the R&D tax credits spillover effect are consistent with the results of Sterlacchini and Venturini (2019) who obtain that the probability to access to public fiscal incentives is higher for firms active in regions with a larger proportion of tax claimants, thus suggesting imitative effects in accessing to R&D tax incentives.

Regarding columns (2) and (3) of Table 4, corresponding to the results of the estimation that account for differences in the drivers of tax credits persistence between large firms and SMEs, we find some common factors to all firms and some remarkable disparities. In particular, we obtain negative duration dependence for both large firms and SMEs, as indicated by the negative and significant coefficient of *log (survival time)*, denoting that the probability of spell ending decreases with the passage of time. Therefore, these results provide evidence that persistence in R&D tax credits is important both for large firms and SMEs.

In addition, among the variables capturing the innovative orientation of the firms, we obtain that undertaking complementary technological activities reduce the risk of spell ending both for large and SMEs. Regarding firm and market characteristics, we obtain that also both for large firms and SMEs, young firms experience shorter spell duration and that the spell duration increases for those firms operating in a high-tech industry. This result is in line with Busom *et al.* (2017) who found that firms in high-tech industries are more likely to use R&D tax credits. However, our results also show some differences in the drivers of persistence for large firms as compared to SMEs. For large firms, export intensity and operating in a med-tech industry are important and significant drivers for the duration of the spells. In the case of SMEs, we obtain that the availability of internal funding increases spell duration. This variable, computed as the ratio of own funds over short-run debt, may be considered as an indicator of the firm' financial capability. This result is in line with other studies that have found a positive relationship between firms' financial capabilities and the probability of using tax credits, in particular in the case of SMEs, see Busom *et al.* (2014, 2017), Czarnitzki *et al.* (2011) and Kobayashy (2014), among others. In addition, facing a high number of competitors in the market decreases the duration of spells for SMEs. Finally, our measure of R&D tax credit spillover, and the indicator of receiving public subsidies increase the spell duration of large firms but have no impact on the duration of spells of SMEs.

6.2. The effect of persistence in claiming R&D tax credits on product innovations.

The second research question is devoted to explore whether persistence in using R&D tax credit influences the achievement of innovation results, in terms of the number of product innovations. The impact of R&D tax credits persistence on product innovation depends, among other factors, on how much tax credits increases R&D spending, and on whether the increase in R&D investment leads to more innovations. Thus, in order to analyse how persistence in the use of tax credits fosters innovations, we control for R&D capital and other inputs considered relevant in the innovation production function (Cappelen *et al.*, 2012).

We use the number of product innovations introduced by the firm in a given year as our measure of innovation output.[13] Thus, our dependent variable is a count variable that requires the estimation of count models. In Table 5 we report the results of the estimation of equation (4) using NB models,[14] including the estimate of persistence in claiming R&D tax credit (spell survival) obtained in the first step. Therefore, the standard errors presented in this Table are bootstrapped standard errors to properly consider that one of the explanatory variables comes from a previous estimation stage.[15]

[Insert Table 5 around here]

The sample we use in this case includes those firms with at least one year of positive R&D spending. The reason to use this broader sample is because we are interested in capturing the effect of persistence in using TC on the achievement of product innovations, beyond the effect of all other factors that may be relevant for the propensity to introduce product innovations. Table 5 reports the estimates of two specifications, the first one corresponding to all firms (column 1) and the second distinguishing between

[13] Although the ESEE also provides information on whether the firm introduces process innovations in a given year, it does not provide information on the number of process innovations, so we cannot use this variable as another measure of innovation results. The ESEE does not provide information either on non-technological innovations, such as organizational or marketing innovations.

[14] In all cases, the parameter capturing over dispersion is statistically significant, indicating the rejection of the Poisson against the NB model.

[15] It is also possible to compute the standard errors using the delta method, but their expressions are highly complicated since at the first step we estimate a discrete time proportional hazard model.

large firms and SMEs using two size group dummies (for large firms and SME, respectively). In this second specification we allow the estimated coefficients of all explanatory variables to vary depending on the firm being a large firm (more than 200 employees) or an SME (columns 2 and 3, respectively). The aim here is to be able to distinguish by group size the impact of each regressor on the number of product innovations.

As our main result, we obtain a positive and significant effect of persistence in using R&D tax credits, measured as the previously estimated spell survival, on the number of product innovations. The impact of persistence in R&D tax credits is high and statistically significant in the specification of column (1), regarding all firms. This result indicates that the duration of the tax credit spell, that is, accumulated years of continuous use of tax credits, enhances the rate at which firms obtain product innovations. We also obtain a non-linear effect of R&D tax credits persistence: the coefficient of the variable capturing the spell survival is positive and highly significant, but its squared value is negative and highly significant, indicating that persistence in R&D tax credits exert a positive but decreasing impact on the expected number of product innovations. This non-linear effect may be interpreted as follows. Continuity in claiming R&D tax credits might induce firms to increase their spending in those R&D projects with greater expected profitability. Therefore, tax credits recipients are expected to obtain a higher number of product innovations, as compared to non-recipient firms. However, as firms persist in using R&D tax credits, they are induced to invest increasingly in less profitable projects, with less expected innovation outcomes. This non-linear effect is also consistent with the idea of David et al. (2000) and Czarnitzki et al. (2011), among others, that tax credits are expected to have a significant effect on R&D investment in the short run, and a small effect in the long run. Our findings are also in line with the works of Czarnitzki *et al.* (2011), who found evidence of a positive effect of R&D tax incentives on innovation output for a sample of Canadian manufacturing firms, and also Cappelen *et al.* (2012), who found a positive relationship between a policy change in the Norwegian R&D tax credit system and the introduction of product innovations.

Using our coefficient estimates in Table 5 we may also provide some quantitative results on the impact of (estimated) persistence on the number of product innovations. In particular, we may calculate the potential increase in the number of innovations between two periods t and t+1 associated with the predicted persistence (spell survival) in using

R&D tax deductions and its squared value. Thus, according to the estimates reported in column (1) of Table 5, and using mean values for all the other explanatory variables, the predicted rise in the number of innovations for a firm that increases its spell survival probability by 10% is 22.62%.[16] We consider that these quantitative values enhance our results on the importance of persistence in the use of R&D tax credits for the achievement of a higher number of product innovations.

Regarding other variables included in the estimation, we obtain that a number of factors related to the innovative orientation of the firms have a positive and significant impact on the number of product innovations, such as receiving public R&D subsidies, undertaking complementary R&D activities and technological collaboration, and the number of R&D employees. In addition, regarding the conditions of the foreign and domestic markets, we also obtain that export intensity, having a high number of competitors in the market and facing a recessive market have a positive and significant impact on the achievement of product innovations. All these results are consistent with the evidence reported in a number of studies explaining the determinants of firms' innovation outcomes (see, e.g., Beneito et al., 2014, 2015).

The results of columns 2 and 3 correspond to the specification distinguishing between large firms and SMEs using two size group dummies. Regarding persistence, our results show that persistence in using R&D tax credits is high and statistically significant only for SMEs. However, persistence in TC is not relevant for the achievement of a higher number of product innovations in the case of large firms. This result could be due to the fact that, compared to SMEs, large firms are to a greater extend regular R&D performers and tax credit claimants, so that continuity in using R&D tax credits is common feature of large firms performing R&D activities. These findings are also consistent with some studies that have found differences between large firms and SMEs regarding their sensitivity to R&D tax credits and effectiveness in terms of R&D spending (Lokshin and Mohnen, 2012; Baghana and Mohnen, 2009, Sterlacchini and Venturini, 2019).

[16] Since the profile of persistence in the specification is non-linear, we can simulate its effect on the number of product innovations along the distribution of persistence. We do not provide here all the results but, as an additional example, the number of product innovations increases by 61.33% if the spell survival probability increases 50%.

Concerning the variables capturing the innovative orientation of the firm, we obtain that receiving public subsidies, undertaking technological collaboration and the number of R&D employees all have a positive and significant effect on the achievement of product innovations both for large firms and SMEs. However, performing internal R&D and performing complementary R&D activities have a significant impact only for large firms. These different results between large firms and SMEs regarding their innovative orientation are consistent with the findings obtained in existing studies. For instance, Baldwin and Gellatly (2003) document that, while large firms' innovation strategies are based on larger research projects that may benefit from scale economies, SMEs innovation activities usually focus on specialization, customization and product flexibility features that rely more often on external interaction and collaboration with other firms. We also observe commonalities and differences between large firms and SMEs in how the conditions of the domestic and foreign markets affect the achievement of product innovations. For both large and SMEs, the number of product innovations increase with export intensity and when facing a recessive market. Having a significant market share increases product innovations in large firms, whereas in the case of SMEs, facing a reduced number of competitors is negatively associated with the introduction of product innovations.

6.3. Sensitivity analysis.

The results we have presented above are robust to a number of additional controls. First, we control for the possibility that firms may carry-forward the use of R&D tax credits. In general, only firms with positive taxable income and positive R&D expenditures will be able to claim tax credits given that these are designed as a deduction from the firm's corporate tax liability. However, firms may carry forward tax credits when these exceed the legal threshold percentage of their tax liability for a given year. This implies that, by not considering this possibility, we could be overestimating the extent of R&D tax persistence since observed persistence could be partially due to previous participation instead of yearly-repeated participation. The ESEE does not provide information on firms' use of carry-forward provisions when claiming tax credits, so we control for this possibility in two ways. First, we control for firms that were claiming tax credits at *t* but did not undertake R&D investments in *t*-1, since this suggests that these firms were probably making use of the carry-forward provision. In Table A2 in Appendix 2 we report the estimation results controlling for those firms that potentially carry forward the use of tax credits. Controlling for firms that claim R&D tax credits and did not invest in R&D in the previous year (around 5% of the observations), we obtain that the duration dependence coefficients for the general specification (column 1) and for large firms (column 2) do not change, whereas the coefficient for small firms (column 3) changes from -0.130 to -0.120 and maintains its level of statistical significance. In general, all the other covariates are similar. Second, we have selected a sample containing only those firms with positive gross profits as a proxy for positive taxable income, since this is the general condition to be able to claim R&D tax credits. The results we obtain are reported in Table A3 in Appendix 2, and we get that the duration dependence coefficient for the general specification (column 1), changes from -0.144 to -0.115 and maintains its level of statistical significance. Further, the duration dependence coefficient for large and small firms (columns 2 and 3), change from -0.129 to -0.087 and from -0.130 to -0.101, respectively. Therefore, we can conclude that our results are robust to these controls, especially regarding negative duration dependence.

Secondly, we consider the issue of left censoring. One difficulty that might arise when measuring persistence as the sum of previous years claiming R&D tax credits is that we do not have information on whether the firm was claiming them before 2001 (which is the first year the survey provides this information). In our working sample a 6,24% of spells are left-censored spells, so that our estimates could lead to a biased duration dependence. Thus, in order to check the robustness of our results to the existence of left-censored spells we have estimated the specifications of Table 4 excluding from the sample those spells that are left-censored, and the results are robust to this exclusion.[17]

Thirdly, we further control for changes in the ownership status of the firm that could affect the duration of the R&D tax credit spell. In particular, we have introduced in estimation of Table 4 two variables controlling, respectively, for firm absorption (indicating that the firm has absorbed another firm) and for firm excision (indicating that

[17] When we exclude left-censored spells the coefficient for duration dependence (i.e., for the variable *Log (survival time)*) in column (1) changes from -0.144 to -0.114, in column (2) it does not change and in column (3) from -0.130 to -0.129. For the sake of space, these results and the rest of robustness are not fully reported but they are available from the authors upon request.

the firm has experienced an excision). We have obtained that the main results hold, and that the coefficients for these variables are generally non-significant in any specification.

Fourthly, regarding the innovation strategy of the firm, in Table 4 we have also considered indicators on whether the firm engages in internal R&D activities and whether the firm reports technological collaboration with other firms or institutions. However, none of these two indicators were significant in any of the specifications, so we have finally not included them.

Finally, we undertake a robustness check of our results regarding persistence by considering only those firms with only one R&D tax credit spell, i.e., excluding those firms with two spells. We obtain in general similar results, in particular regarding negative duration dependence (the duration dependence coefficient for the general specification in this case is equal to -0.124, and statistically significant only at the 1% level).

7. Concluding remarks.

In this study we have investigated whether there is persistence in the use of R&D tax credits by firms using a firm-level panel data sample of Spanish manufacturing firms. We have also evaluated the effectiveness of R&D tax credits in inducing firms to achieve a higher number of product innovations. Our findings provide strong support to the existence of persistence in the use of R&D tax credit by firms, suggesting that the fact of continuously benefiting from R&D tax credits is in part a self-sustained process. We also find significant differences in the drivers of persistence between small and large firms. In addition, our results indicate that persistence in the use of R&D tax credits has a significant and positive impact on the achievement of product innovation, especially in the case of small firms. We obtain that this impact is non-linear, so that persistence in R&D tax credits exert a positive but decreasing impact on the expected number of product innovations. This finding suggest that R&D tax credits are expected to have a significant effect on product innovations in the short run, but a small effect in the long run.

These findings have important policy implications. First, since the duration in claiming R&D tax credits by firms is in part a self-sustained process, any policy measure to encourage firms to start claiming R&D tax credits, will have an induced effect in the long run, thereby increasing the effectiveness of the fiscal incentives to R&D. The use of tax credits is common among large firms. However, becoming users is more difficult for SMEs (due to several reasons such as unawareness, administrative costs or complexity in the application process). Thus, policy makers should try to extend awareness of this fiscal instrument among these companies and facilitate and simplify the claiming procedure.

Secondly, our results suggest that fiscal policies should aim at encouraging firms to continuously use R&D tax credits as a way to intensify the efficiency of R&D investments in terms of innovation results, especially in the case of SMEs. We obtain that persistence in using R&D tax credits is particularly effective for the achievement of product innovations for SMEs. Therefore, fiscal authorities should discriminate the instrument attending to firms' size and promote the use of R&D tax credits specially in the case of SMEs. This is particularly relevant in the case of Spain, since the structure of the manufacturing sector is mainly composed by small firms. This is reinforced by the fact that large firms usually have proportionately greater internal resources that may translate into product innovations (R&D capital stock and internal R&D) while SMEs usually need external support when undertaking R&D investments. Thus, policy makers and fiscal authorities have the responsibility of extending the acknowledgement and use of the tax instrument among SMEs, which, in a higher proportion than large firms, either do not know the existence of R&D tax credits, or decide not to claim them because of the burden of administrative costs, inexperience or distress to deal with tax authorities.

Third, as recommended by the OECD (Appelt *et al.,* 2016), governments should continue to update the R&D tax system, reduce its costs and promote how to apply for tax credits, especially among SMEs in order to facilitate the continuity in the use of R&D tax credits. Finally, policy makers should provide a tax scheme not only generous but also stable over time, to induce firms to confidently plan and implement their R&D projects and to obtain innovative outcomes from their R&D investments.

From a managerial point of view, our results indicate that innovative business strategies should be oriented towards a continuous use of R&D tax credits, since persistence in its use seem to lead to higher innovation results in terms of product innovations. In addition, managers should also consider enhancing those factors that seem to be associated with the duration in claiming R&D tax credits, an in particular undertaking complementary R&D activities, such as technical and scientific information services, quality controls and/or market and marketing studies for the commercialization of new products.

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Appendix 1. Data and variables

Table A.1. Definition of variables.

Variable name	Definition
Log(Survival Time)	Log of survival time (baseline hazard), taking values from 1 to 13 (maximum spell duration)
Stable R&D performer	Dummy variable taking the value of 1 if the firm engages in R&D activities on a regular basis (i.e., every observed year) and 0 otherwise.
Log(R&D capital stock)	Log of the stock of R&D capital, measured using the perpetual inventory method, assuming a depreciation rate of 15% and with current R&D expenditures deflated using industrial prices for the manufacturing sector.
Product and process innovation	Dummy variable taking the value of 1 if the firm declares to have introduced any product or process innovation, and 0 otherwise
Complementary R&D activities	Dummy taking the value of 1 if the firm reports that it uses one of the following: technical and scientific information services, quality controls on a systematic basis, and/or market and marketing analysis for the commercialization of new products and 0 otherwise.
% of R&D employees	Percentage of R&D employees over the total workforce of the firm
Hired R&D employees	Dummy variable taking the value of 1 if the firm reports to have hired employees with professional experience in the public system of R&D, and/or employees with business experience in R&D, and 0 otherwise.
Appropriability	Log of the ratio of the industry-year total number of patents and utility models over the total number of firms that assert to have achieved innovations (either product or process, or both), using two-digit NACE-2009 industry classification.
Internal R&D	Dummy taking the value of 1 if the firm undertakes internal R&D activities and 0 otherwise.
Technological collaboration	Dummy variable taking the value of 1 if the firm reports technological collaboration with universities or technological centres, and/or with other firms (customer, suppliers or competitors).
Log (employment)	Log of the number of employees.
Young firm	Dummy variable taking the value of 1 if the firm' age is up to 5 years old, and 0 otherwise.
Recessive market	Dummy variable taking the value of 1 if the firm assess to face a recessive market, and 0 otherwise.
Significant market share	Dummy variable taking the value of 1 if the firm reports having a significant market share in its main market, and 0 otherwise.
N. competitors 0-10	Dummy variable taking the value of 1 if the firm reports that it faces less than ten competitors with significant market share in its main market, and 0 otherwise.
N. competitors 11-25	Dummy variable taking the value of 1 if the firm reports that it faces more than 10 but less than 25 competitors with significant market share in its main market, and 0 otherwise.
N. competitors +25	Dummy variable taking the value of 1 if the firm reports that it faces more than 25 competitors with significant market share in its main market, and 0 otherwise.
Med-tech industry	Dummy variable taking the value of 1 if the firm belongs to a medium technological intensive industry, and 0 otherwise.
High-tech industry	Dummy variable taking the value of 1 if the firm belongs to a high technological intensive industry, and 0 otherwise.
Own financial resources	Log of the ratio of firm own funds to short-run debt.
Export intensity	Ratio of the volume of exports over sales
R&D tax credit spillover	Average number of firms within the same market benefiting from R&D tax credits. Market defined as the result of crossing the 20 two-digit industries breakdown with the 17 Spanish autonomous communities (regions).
Public R&D finance	Dummy variable taking the value of 1 if the firm reports to have received an R&D subsidy, and 0 otherwise.

SME	Dummy variable taking the value of 1 if the firm has more than 10 but less or equal than 200 employees, and 0 otherwise.
Large firm	Dummy variable taking the value of 1 if the firm has more than 200 employees, and 0 otherwise.
Two-digit ISIC industries	1. Meat; 2. Food and Tobacco; 3. Drinks; 4. Textile; 5. Leather and Shoes; 6. Timber; 7. Paper; 8. Printing Products; 9. Chemical and Pharmaceutical Products; 10. Plastic and Rubber; 11. Non-metallic Minerals; 12. Metals; 13. Metallic Products; 14. Agricultural and Industrial Machinery; 15. Electronics and Data Processing; 16. Electrical Materials and Accessories; 17. Motors and Vehicles; 18. Other Transport Materials; 19. Furniture; 20. Other manufacturing industries.

Appendix 2. Sensitivity analysis

Table A2. Maximum likelihood estimates for the discrete time proportional hazards models. Controlling for carrying forward.

	R&D tax credit duration		
	All Firms (1)	**Large (2)**	**Small (3)**
Persistence effects			
Log (survival time)	-0.145***	-0.129***	-0.120*
	(0.042)	(0.048)	(0.083)
Innovation strategy of the firm			
Log (R&D capital stock)	0.021	0.089	-0.022
	(0.084)	(0.110)	(0.160)
Product and process innovations	-0.115	-0.119	-0.082
	(0.184)	(0.261)	(0.319)
Complementary R&D activities	-0.514***	-0.601**	-0.756**
	(0.191)	(0.282)	(0.317)
% of R&D employees	1.222	2.618	0.620
	(1.376)	(2.821)	(2.058)
Hired R&D employees	0.236	0.392	0.011
	(0.222)	(0.293)	(0.464)
Appropriability	-0.138	-0.135	-0.209
	(0.089)	(0.121)	(0.153)
Firm and market characteristics			
Log(employment)	0.166	-0.134	0.050
	(0.105)	(0.164)	(0.273)
Young firm	0.828***	0.874**	0.761*
	(0.273)	(0.412)	(0.452)
Own financial resources	-0.673*	-0.161	-1.393*
	(0.385)	(0.510)	(0.715)
Recessive market	0.100	0.364	-0.566
	(0.185)	(0.246)	(0.352)
Significant market share	-0.470	-0.799	-0.395
	(0.380)	(0.514)	(0.800)
N. competitors 0-10	-0.431	-0.253	-0.357
	(0.273)	(0.365)	(0.499)
N. competitors 10-25	-0.202	0.499	-0.876
	(0.320)	(0.430)	(0.544)
N. competitors +25	0.379	0.307	1.239**
	(0.407)	(0.645)	(0.606)
Med-tech industry	-0.405*	-0.536*	-0.632
	(0.209)	(0.282)	(0.394)
High-tech industry	-0.466*	-0.914**	-0.961**
	(0.272)	(0.392)	(0.469)
Export intensity	-0.619**	-0.687*	-0.771
	(0.278)	(0.352)	(0.564)
Other controls			
R&D tax credit spillover	-0.993*	-1.501**	0.904
	(0.524)	(0.725)	(0.773)

Public R&D finance	-0.426**	-0.451*	-0.316
	(0.177)	(0.233)	(0.346)
Carry forward	-0.033	-0.033	0.197
	(0.315)	(0.462)	(0.491)
Constant	0.862	-0.826	
	(0.696)	(0.985)	
Year dummies	YES	YES	
Test for unobserved individual heterogeneity			
Chibar2(01)	7.6e-05	3.6e-05	
p-value	(0.497)	(0.498)	
Number of observations	1,042	977	

Notes:

1. The unit of observation is the R&D tax credit spell of the firm, defined as a period of continuous use of R&D tax credits.
2. Sample of firms that invest in R&D and claim R&D tax credits.
3. Columns 2 and 3 correspond the joint estimation of small and large firms.
4. *,**,*** indicate significant at 10%, 5% and 1% levels, respectively.

Table A3. Maximum likelihood estimates for the discrete time proportional hazards models. Firms with positive gross profits.

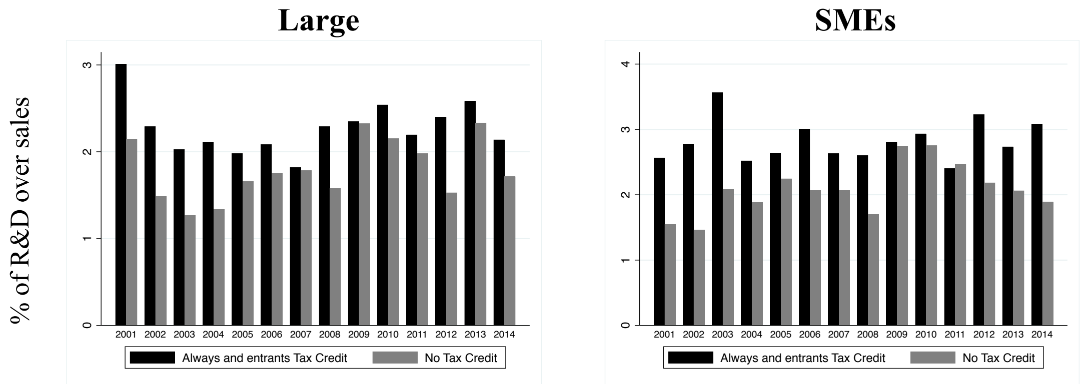
	R&D tax credit duration		
	All Firms (1)	**Large (2)**	**Small (3)**
Persistence effects			
Log (survival time)	-0.115***	-0.087*	-0.101
	(0.043)	(0.048)	(0.083)
Innovation strategy of the firm			
Log (R&D capital stock)	0.109	0.233	-0.055
	(0.093)	(0.134)	(0.171)
Product and process innovations	-0.069	-0.005	-0.170
	(0.197)	(0.280)	(0.336)
Complementary R&D activities	-0.513**	-0.636**	-0.720**
	(0.206)	(0.311)	(0.334)
% of R&D employees	0.286	1.184	0.772
	(1.587)	(3.196)	(2.205)
Hired R&D employees	0.211	0.338	-0.052
	(0.233)	(0.315)	(0.472)
Appropriability	-0.102	-0.069	-0.153
	(0.095)	(0.130)	(0.161)
Firm and market characteristics			
Log(employment)	0.064	-0.302*	0.194
	(0.114)	(0.180)	(0.288)
Young firm	0.895***	0.987**	0.823*
	(0.293)	(0.439)	(0.479)
Own financial resources	-0.765**	-0.572	-1.106*
	(0.409)	(0.552)	(0.726)
Recessive market	-0.004	0.204	-0.670*
	(0.201)	(0.275)	(0.365)
Significant market share	-0.457	-0.698	-0.655

	(0.407)	(0.555)	(0.858)
N. competitors 0-10	-0.491	-0.305	-0.444
	(0.285)	(0.389)	(0.484)
N. competitors 10-25	-0.122	0.629	-0.848
	(0.331)	(0.457)	(0.550)
N. competitors +25	0.439	0.329	1.373**
	(0.413)	(0.664)	(0.613)
Med-tech industry	-0.463**	-0.608**	-0.606
	(0.223)	(0.304)	(0.413)
High-tech industry	-0.668**	-1.263***	-1.012**
	(0.299)	(0.441)	(0.494)
Export intensity	-0.591**	-0.629*	-0.916*
	(0.295)	(0.377)	(0.586)
Other controls			
R&D tax credit spillover	-0.721	-1.143*	0.821
	(0.541)	(0.763)	(0.798)
Public R&D finance	-0.424**	-0.466*	-0.327
	(0.187)	(0.249)	(0.355)
Constant	-1.170	-1.026	
	(0.746)	(1.009)	
Year dummies	YES	YES	
Test for unobserved individual heterogeneity			
Chibar2(01)	5.4e-05	2.6e-05	
p-value	(0.497)	(0.498)	
Number of observations	946	886	

Notes:

1. The unit of observation is the R&D tax credit spell of the firm, defined as a period of continuous use of R&D tax credits.
2. Sample of firms that invest in R&D and claim R&D tax credits.
3. Columns 2 and 3 correspond the joint estimation of small and large firms.
4. *,**,*** indicate significant at 10%, 5% and 1% levels, respectively.

Figure 1. Firms' effort in R&D.



Notes:

1. Effort in R&D is measured as R&D expenditures over sales.
2. No Tax Credit refers to firms than never use R&D tax credits.
3. Always and entrants Tax Credit correspond to firms that claim R&D tax credit on a regular basis.
4. Firms than use tax credits only occasionally are not included.
5. Sample of firms with positive spending in R&D.

Figure 2. Kaplan-Meier survival estimates for claiming R&D tax credits.

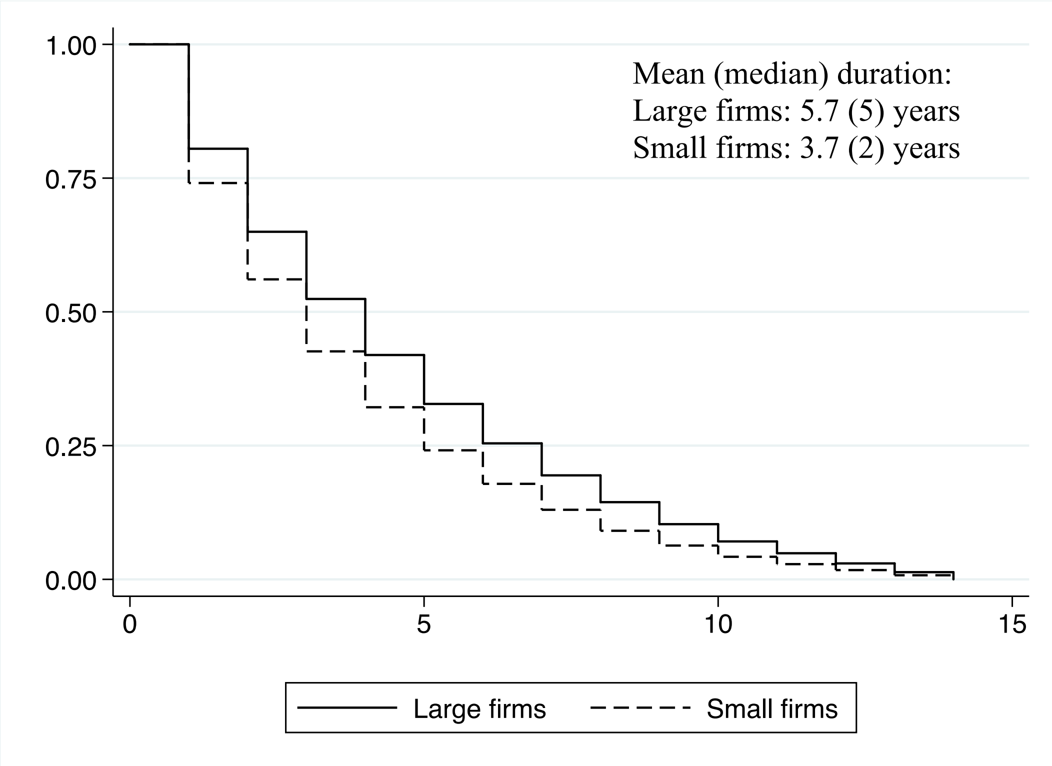


Table 1. Evolution of the Spanish tax credit scheme.

Tax Credit (%)	2004-06	2007	2008-10	2011	2012-13	2014
R&D Activities						
Current R&D expenditures (%)	30	27	25	25	25	25
Expenditures on R&D personnel (%)	20	18	17	17	17	17
R&D capital expenditures (assets except buildings) (%)	10	9	8	8	8	8
Incremental R&D expenditures[1] (%)	50	46	42	42	42	42
ºCooperation with universities and Technological Centres (%)	20	-	-	-	-	-
Technological Innovation						
Current expenditures in technological innovation (%)	10-15	9	8	8[2] 12[3]	12	12
Apply to both activities						
Cap in tax liability (%)	35/50	35/50	35/50	35/50[2] 35/60[3]	25/50	25/50[4]
Carry-forward excess (n. of years)	15	15	15	15	18	18

Notes:

Figures indicated as (%) refer to the percentage of the qualifying R&D expenditure that may be deducted from corporate tax liability, i.e., tax credit, in each case.

1. Incremental R&D expenditures refers to the excess of current R&D expenditures over the average of the previous 2 years.
2. Applies from January 1, 2011 to March 5, 2011.
3. Applies from January 6, 2011 onwards.
4. Caps in volume may also hold in some special cases

Table 2. Transition probabilities of R&D tax credit status.

R&D tax credit in t-1	R&D tax credit in t	
	No tax credit	Tax credit
All firms		
No tax credit	86.14	13.86
Tax credit	20.76	79.24
Large firms		
No tax credit	84.40	15.60
Tax credit	18.54	81.46
SMES		
No tax credit	87.90	12.10
Tax credit	23.68	76.32

Note: Sample of firms with positive spending in R&D.

Table 3. R&D tax credit persistence and product innovations.

	Large firms			Small firms		
Years of R&D tax credits (by intervals)	**% of obs.**	**Number of product innovations**	**R&D expenditures**	**% of obs.**	**Number of product innovations**	**R&D expenditures**
1-2	11.15	2.72	8.84	23.45	4.37	7.24
3-4	15.29	2.60	9.05	20.59	1.95	7.50
5-6	16.63	5.22	9.18	19.61	4.04	7.65
7-8	15.10	2.38	9.41	16.19	9.66	8.08
9-10	17.55	1.42	9.56	8.09	4.56	7.95
11-12	10.58	2.71	10.06	4.54	1.84	8.18
13-14	13.09	3.48	9.78	7.54	5.72	8.10
Number of obs.	2,080			1,433		

Notes:

1. Sample of firms with positive spending in R&D.
2. The first column refers to the number of consecutive years of claiming R&D tax credit (by intervals).
3. Both the number of product innovations and R&D expenditures are annual averages per firm.
4. R&D expenditure is measured in real terms and in logs.

Table 4. Maximum likelihood estimates for the discrete time proportional hazards models.

	R&D tax credit duration		
	All Firms (1)	**Large (2)**	**Small (3)**
Persistence effects			
Log (survival time)	-0.144***	-0.129***	-0.130*
	(0.0408)	(0.048)	(0.081)
Innovation strategy of the firm			
Log (R&D capital stock)	0.023	0.090	-0.022
	(0.083)	(0.107)	(0.160)
Product and process innovations	-0.112	-0.119	-0.0919
	(0.183)	(0.258)	(0.318)
Complementary R&D activities	-0.515***	-0.601**	-0.746**
	(0.190)	(0.282)	(0.316)
% of R&D employees	1.225	0.390	0.0236
	(1.376)	(0.291)	(0.462)
Hired R&D employees	0.235	2.587	0.592
	(0.222)	(2.802)	(2.054)
Appropriability	-0.137	-0.133	-0.221
	(0.089)	(0.121)	(0.150)
Firm and market characteristics			
Log(employment)	0.165	-0.141	0.056
	(0.105)	(0.161)	(0.272)
Young firm	0.828***	0.869**	0.748*
	(0.273)	(0.411)	(0.449)
Own financial resources	-0.670*	-0.166	-1.393*
	(0.383)	(0.508)	(0.715)
Recessive market	0.0983	0.362	-0.536
	(0.184)	(0.246)	(0.344)
Significant market share	-0.470	-0.797	-0.419
	(0.380)	(0.513)	(0.804)
N. competitors 0-10	-0.430	-0.259	-0.357
	(0.273)	(0.364)	(0.469)
N. competitors 10-25	-0.202	0.491	-0.865
	(0.320)	(0.429)	(0.543)
N. competitors +25	0.377	0.300	1.257**
	(0.407)	(0.645)	(0.603)
Med-tech industry	-0.405*	-0.534*	-0.633
	(0.209)	(0.280)	(0.394)
High-tech industry	-0.467*	-0.915**	-0.936**
	(0.272)	(0.392)	(0.465)
Export intensity	-0.619**	-0.685*	-0.789
	(0.278)	(0.352)	(0.561)
Other controls			
R&D tax credit spillover	-0.987*	-1.486**	0.860
	(0.521)	(0.719)	(0.766)
Public R&D finance	-0.426**	-0.449*	-0.350
	(0.175)	(0.231)	(0.336)
Constant	0.880	-0.775	
	(0.696)	(0.950)	
Year dummies	YES	YES	
Test for unobserved individual heterogeneity			
Chibar2(01)	4.3e-04	3.8e-05	

p-value	(0.492)	(0.498)
Number of observations	1,042	977

Notes:

1. The unit of observation is the R&D tax credit spell of the firm, defined as a period of continuous use of R&D tax credits.
2. Sample of firms that invest in R&D and claim R&D tax credits.
3. Columns 2 and 3 correspond the joint estimation of small and large firms.
4. *, **, *** indicate significant at 10%, 5% and 1% levels, respectively.

Table 5. Count estimates for the number of product innovations.

Variables	All Firms (1)	Large firms (2)	SMEs (3)
Persistence (estimate of survival)	2.582***	0.008	3.253***
	(0.577)	(0.707)	(0.795)
Persistence squared	-2.489***	-0.412	-2.245***
	(0.563)	(0.709)	(0.739)
Log (R&D capital stock)$_{t-1}$	0.004	0.011	0.051
	(0.026)	(0.029)	(0.043)
Public R&D finance $_{t-1}$	0.386***	0.386***	0.446***
	(0.089)	(0.111)	(0.147)
Internal R&D	0.143	0.366*	-0.212
	(0.142)	(0.219)	(0.185)
Complementary R&D activities	0.268***	0.509***	-0.017
	(0.099)	(0.142)	(0.138)
Technological collaboration	0.555***	0.441***	0.552***
	(0.101)	(0.151)	(0.137)
R&D Employees	0.441***	0.519**	0.540***
	(0.139)	(0.216)	(0.191)
Export intensity	0.557***	0.458**	0.360*
	(0.166)	(0.205)	(0.213)
N. competitors 0-10	-0.244*	-0.221	-0.567***
	(0.126)	(0.195)	(0.178)
N. competitors 10-25	-0.152	0.203	-0.804***
	(0.155)	(0.228)	(0.212)
N. competitors +25	0.387**	0.462	0.367
	(0.197)	(0.292)	(0.280)
Recessive market	0.432***	0.354***	0.460***
	(0.0941	(0.120)	(0.141)
Significant market share	-0.029	0.298**	0.096
	(0.206)	(0.134)	(0.124)
Constant	-0.234	0.214	
	(0.467)	(0.467)	
Year dummies	YES	YES	
Industry dummies	YES	YES	
Over dispersion test			
H_0: ϕ=0	4.1e04***	3.5e04***	
p-value	(0.000)	(0.000)	
N. observations	4,056	4,056	
Test for the difference in persistence (estimate of survival) between large and small firms			
Coefficient of the difference = -3.244*** *p*-value 0.002			

Notes:

1. Bootstrapped standard error in parenthesis.
2. *,**,*** indicate significant at 10%, 5% and 1% levels, respectively.